INVENTORY AND DISTRIBUTION OF *AGAVE* (AGAVACEAE) SPECIES IN JALISCO, MEXICO

Gerardo Hernández-Vera
Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco A.C. Av. Normalistas 800 S.H. Colinas de la Normal 44270 Guadalajara Jalisco, MÉXICO

Miguel Cházaro Basañez
Centro Universitario de Ciencias Sociales y Humanidades, departamento de Geografía Universidad de Guadalajara Guanajuato 1045 Guadalajara Jalisco, MÉXICO

Ericka Flores-Berrios
Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco A.C. Av. Normalistas 800 S.H. Colinas de la Normal 44270 Guadalajara Jalisco, MÉXICO

ABSTRACT

In order to review and update the list of *Agave* species previously reported for Jalisco, Mexico, an extensive botanical exploration was done throughout representative areas of the state. Twenty-three species were registered; from which 7 represent new records for Jalisco, and 3 proposed as new species. Fifty per cent of the listed species were found in pine and pine-oak forests, whereas 29% were found in the tropical deciduous forest. Among the many factors that might affect the distribution of agaves, edaphic factors and moreover physiography, can play an important role.

RESUMEN

Con la finalidad de hacer una revisión y actualizar el listado de especies de *Agave* previamente reportadas para Jalisco, se realizó una extensa exploración botánica por el estado. Se registraron 23 especies, de las cuales 7 representan nuevos registros para Jalisco y 3 se proponen como nuevas especies. El cincuenta por ciento de las especies enlistadas se encontró en los bosques de pino y pino-encino, mientras que el 29% prospera en bosque tropical caducifolio. Entre los diversos factores que pueden afectar la distribución de los agaves, se plantea que los edáficos y en especial la fisiografía pueden jugar un papel importante.

INTRODUCTION

In Mexico, the genus *Agave* L. is of great importance since many of its species are used for food, in the manufacture of fibers for threads and textile industry, as ornamental plants, and mainly in the production of different types of alcoholic beverages such as tequila and mezcal (Gentry 1982; Valenzuela 1997; Nobel 1998.). This genus comprehends more than 200 species, from which 75% are in Mexico, which is considered as the center of origin (Granick 1944; García-Mendoza 2002).

In Jalisco, the study of the genus *Agave* has focused basically on *Agave tequilana* Weber var. *azul*. Because of its importance as the only species allowed by the Official Mexican Standard for tequila production, the alcoholic beverage traditionally associated with Mexico, and in particular Jalisco (Cedeño 1995; DOF 1997). In contrast, the study of other non-cultivated agaves many of which are useful species that occur throughout the State, has been neglected.

For Jalisco, Gentry (1982) reports 14 species, whereas McVaugh (1989) reports 18, considering some of them as "doubtful" and "excluded" due to the lack of herbarium specimens and information about wild populations. Thus, based on our collections, the aim of this study was to update the list of species, corroborate in the field McVaugh and Gentry's reports, and contribute to the knowledge of *Agave* species distribution in Jalisco.

Site Description

Located in the western region of Mexico, Jalisco is one of the largest states consisting of 80,000 Km^2 and 4 physiographic provinces: a) Western Sierra Madre, in the northern part of the state, b) Central Plateau, northeast region, c) Trans-Volcanic Belt (Eje Neo-volcanico), central region of the state, and d) Southern Sierra Madre, southwest region (INEGI 2003). Igneous rock soils constitute 79% of its surface, which is favored by several vegetation types, such as conifer and oak forests, tropical subdeciduous forest, tropical deciduous

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forest, tropical savanna, gallery forest, alpine tundra, thorn forest, and cloud forest. The topography ranges from 0–4360 m above sea level (INEGI 2003). All of these geographical and geological characteristics contribute to its floristic diversity, which is estimated to be 7000 plant species (Cházaro & Lomelí 1995).

MATERIALS AND METHODS

Twenty field trips were carried out throughout representative areas of the state of Jalisco in 2002 and 2003. Identification of the species was done according to Gentry's (1982) and McVaugh's (1989) descriptions and/or taxonomic keys. Vegetation types were registered as well as altitude and geographical coordinates by means of a global positioning system (GPS *Magellan 320*). Plants were collected and documented for herbarium specimens deposited at IBUG and IEB herbaria.

RESULTS AND DISCUSSION

Out of 102 collected specimens 23 species were identified, from which seven of them represented new records for the state and three were treated as new species (Table 1). Description of the species *Agave* sp. nov. ined. ("Colimilla" ravine) and *Agave* sp. nov. ined. (Tequila municipality) are in preparation, whereas *Agave vazquezgarciae* is in press (Cházaro et al. in press).

From Gentry's (1982) and McVaugh's (1989) reports, *Agave stringens* Trel., *A. hookeri* Jacobi, *A. cantala* Roxb., *A. impressa* Gentry and *A. longisepala* Todaro, were not located. *A. stringens* was reported by Gentry based on a Trelease collection in Rio Blanco (Zapopan municipality) (Gentry 1982). At the cited location we only found *A. guadalajarana* Trel., (Fig. 1), however according to the vegetation type and Trelease original plant description (Trelease 1920), we assume *A. stringens* could be a form of *A. angustifolia* Haw.

McVaugh (1989) cites a Diguet`s collection for *A. hookeri* from Cerro Viejo (Tlajomulco and Jocotepec municipalities). It is likely that Diguet identified incorrectly the specimen, since the only species found there, was the closely related *A. inaequidens* Koch which spreads throughout the oak and pine-oak forests in the "Sierra del Tigre" (Fig. 2). Gentry (1982) reported a collection for *A. hookeri* south of Jalisco near Jiquilpan (Michoacan state); it appears this species has been introduced from Michoacan state as a cultivar.

With regard to *Agave cantala*, we could not find it near Villa Guerrero as reported by Gentry (1982) who was unsure about the identification of the plant he collected. Perhaps this is a species related to *A. tequilana* Weber, as suggested by Trelease (1920) and Valenzuela and Nabhan (2003), who treat it as a synonym of *A. vivipara* L. *Agave impressa* was not found in the "Sierra de los Huicholes" (Bolaños) as Gentry was informed (Gentry 1982). Probably there was confusion with the common name since he was given the name "masparillo" for this agave in the type locality (Escuinapa, Sinaloa); the same name is used for *A. maximiliana* Baker, abundant in the "Sierra de los Huicholes". For *A. longisepala*, McVaugh (1989) concluded there was uncertainty about its identity and taxonomic position, and Gentry (1982) knew the species only from an illustration. This could be a synonymous for *A. tequilana* since Trelease (1920) reported it as a related species cultivated near Tequila, Jalisco.

Whereas *Agave americana* L. var. expansa (Jacobi) Gentry and *A. tequilana* were found as cultivated species, *A. salmiana* Otto ex Salm, ssp. crassispina (Trel.) Gentry, was found as wild populations in northeast Jalisco (Sierra Cuatralba) (Fig. 3). McVaugh (1989) had reported it as a cultivated species. Considered by Gentry (1982) as a relatively rare species, *A. attenuata* Salm-Dyck was found in "Rincón de Manantlán," south of Jalisco (Fig. 2). We could corroborate the presence of large stems in this species, clearing the uncertainty about this agave's feature reported by McVaugh (1989) (Fig. 4).

The higher number of species was found in the pine and pine-oak forests, being the tropical deciduous forest the second one in harboring the highest diversity (Fig. 5). Hence, the distribution of *Agave* species based on physiographic provinces shows that they are mainly concentrated in southern Sierra Madre and Trans-Volcanic Belt (Eje Neovolcanico), which are two areas whose main vegetation types are tropical deciduous forest and pine and pine-oak forests, respectively (Figs. 1–3, 6).

These results are similar to those presented by García-Mendoza (2002) who reports that in Mexico,

TABLE 1. *Agave* species in Jalisco, México. New record for Jalisco §. New species ¤.

Group	Species
Rigidae	*Agave angustifolia* Haw.
	§ Agave rhodacantha Trel.
	Agave tequilana Weber
Crenatae	*Agave inaequidens* Koch.
	Agave maximiliana Baker
Marmoratae	*Agave gypsophila* Gentry
	Agave valenciana Cházaro & A. Vazquez,
Parryanae	*Agave guadalajarana* Trel.
	§ Agave parryi Engelm.
Ditepalae	*§ Agave wocomahi* Gentry
Salmianae	*§ Agave salmiana* Otto ex Salm-Dyck
Total for subgenus *Agave*	11
Amolae	*Agave pedunculifera* Trel.
	Agave attenuata Salm-Dyck
	Agave vilmoriniana Berger
	¤ *Agave vazquezgarciae* Cházaro, Valencia & Lomelí, sp. nov.
Filiferae	*Agave colimana* Gentry
	Agave schidigera (Lem.) (sensu Gentry)
	§ Agave filifera Salm-Dyck (sensu Gentry)
	§ Agave geminiflora (Tagl.) Ker-Gawler
Marginatae	*§ Agave angustiarum* Trel.
	¤*Agave* sp. nov. ined. ("Colimilla" ravine, municipalities of Tonalá and Zapotlanejo)
	¤ *Agave* sp. nov. ined. (municipality of Tequila)
Striatae	*Agave rzedowskiana* P. Carrillo, R. Vega & R. Delgad.
Total for subgenus *Littaea*	**12**
Total species	**23**

tropical deciduous forests and coniferous and oak forests are among the vegetation types with the highest number of *Agave* species, only surpassed by deserts and chaparrales. Nevertheless, it was found that several species are not exclusive or restricted to a certain vegetation type since they can either thrive in two or more types or can be found in ecotones (Table 2). Soil characteristics can play an important role in the distribution of agaves as has been suggested by Nobel & Berry (1985), who conclude that although soil types have not been systematically related to the distribution of agaves, edaphic factors may affect their seedling establishment. In this study, the two physiographic provinces with the highest number of *Agave* species (Southern Sierra Madre and Neo-Volcanic Belt) are conformed mainly by igneous rocks, a soil type previously reported as favored by these plants (Álvarez de Zayas 1989; García-Mendoza 2002).

Agave angustifolia Haw., *A. schidigera* Lem. (sensu Gentry) and *A. maximiliana* Baker, were the most widely distributed species, thriving in many different vegetation types in a broad range of altitudes and latitudes throughout the state (Table 2; Figs. 1, 3 & 6). This could reflect their ample tolerance limits to each of the several environmental factors, based on high levels of genetic diversity as reported for *A. angustifolia* (Colunga-GarcíaMarín et al. 1999). In contrast, *A. gypsophyla* Gentry and *A. geminiflora* (Tagl.) Ker-Gawler, were found in small areas associated to specific geographical and ecological conditions such as soil type and vegetation. Only a small population of *A. geminiflora* was observed, thriving in an oak woodland along a rocky brook 1814 m above sea level, in the central region of Jalisco (municipality of Tequila). In the other hand, *A. gypsophyla* could be found only in rocky gypsum soils (whence the name) south of the state, municipality of Pihuamo (Fig. 2).

Agaves in the subgenus *Agave* were found likely to thrive in flatlands, whereas agaves in the subgenus

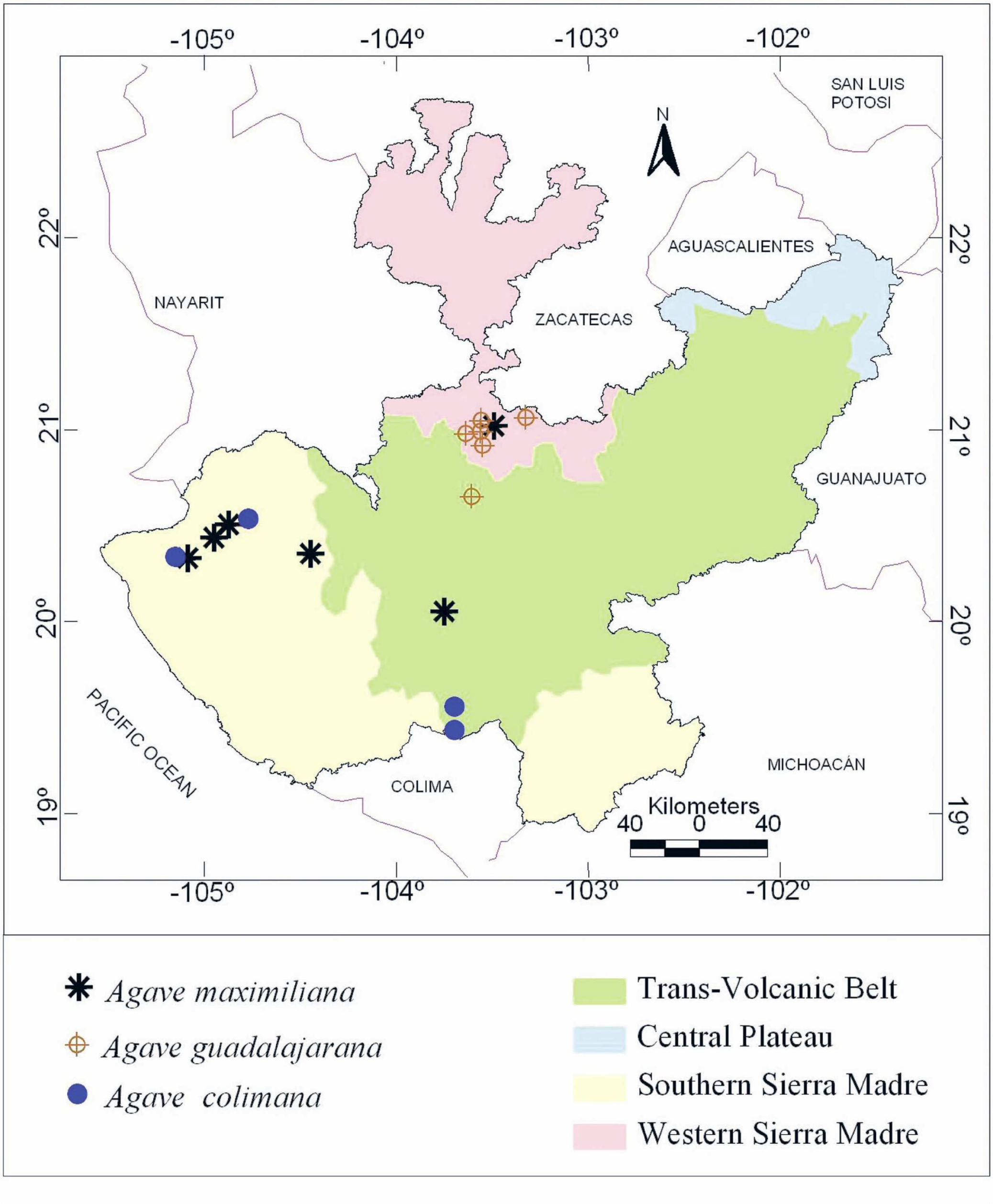
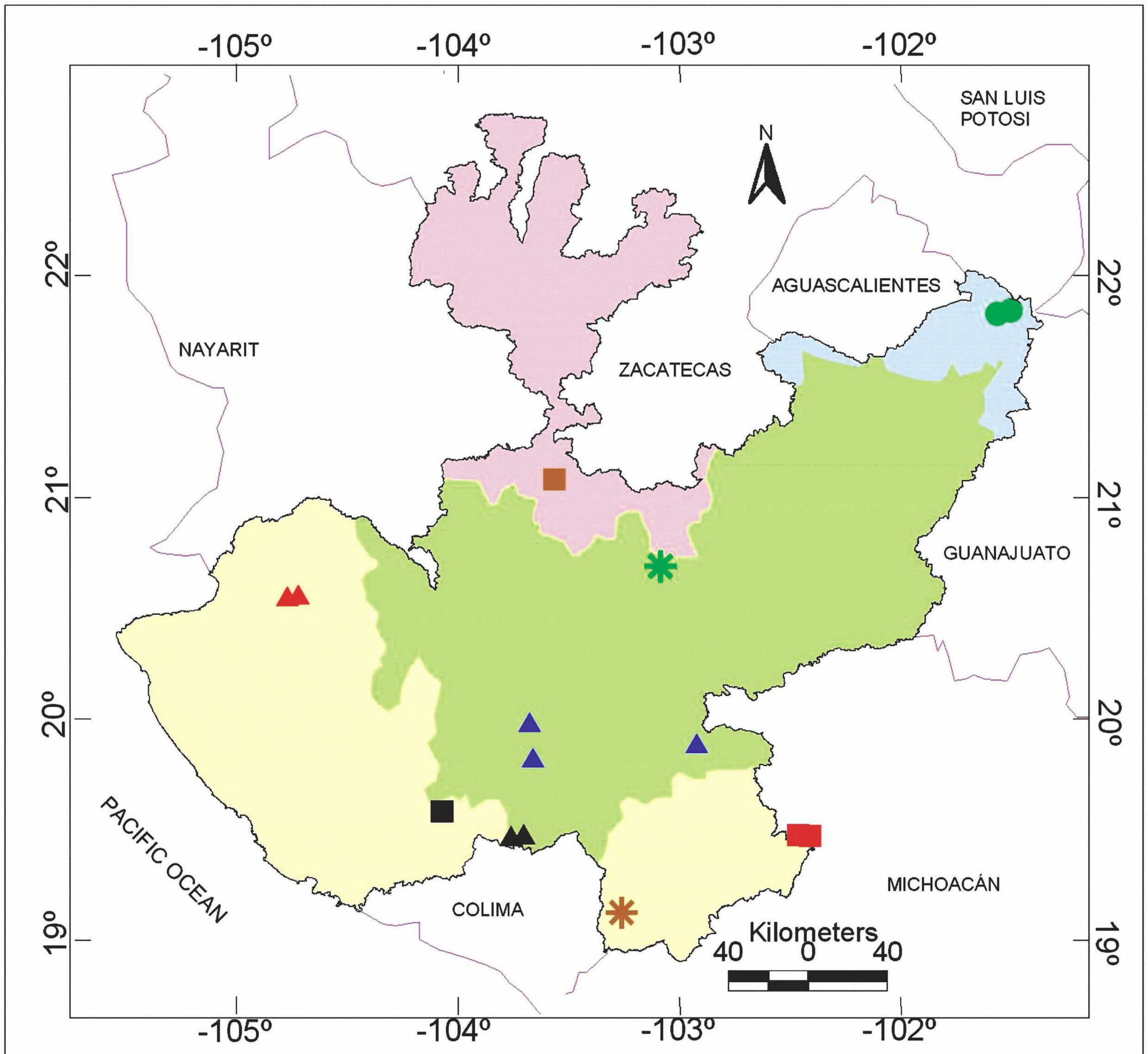


Fig. 1. Distribution of *Agave maximiliana, A. guadalajarana,* and *A. colimana.*

Littaea, appear to grow mainly in sharp rocky cliffs (66% of this subgenus specimens were found exclusively in this habitat). Gentry (1982), suggests that the subgenus *Littaea* could represent the phylogenetic and geologically older form of agaves, predominantly diploid with more "primitive" leaf and habit characteristics (Granick 1944). Hence, thriving in sharp rocky slopes could represent a "primitive" growth habit, relying more on their toxic substances in the leaves and inaccessible cliff sites for survival than on defensive armor. Most in the subgenus *Littaea*, lacked of marginal spines or "teeth," or if present, they were fragile and brittle



- *Agave parryi*
- *Agave ineaquidens*
- *Agave angustiarum*
- *Agave valenciana*
- *Agave vazquezgarciae*
- *Agave gypsophila*
- *Agave sp. nov. ined.* ("Colimilla" ravine, municipalities of Tonalá and Zapotlanejo)
- *Agave attenuata*
- *Agave gemimiflora*

- Trans-Volcanic Belt
- Central Plateau
- Southern Sierra Madre
- Western Sierra Madre

FIG. 2. Distribution of *Agave parryi, A. inaequidens, A. angustiarum, A. valenciana, A. vazquezgarciae, A. gypsophila, A. attenuata, A. geminiflora,* and *Agave* sp. nov. ined. ("Colimilla" ravine).

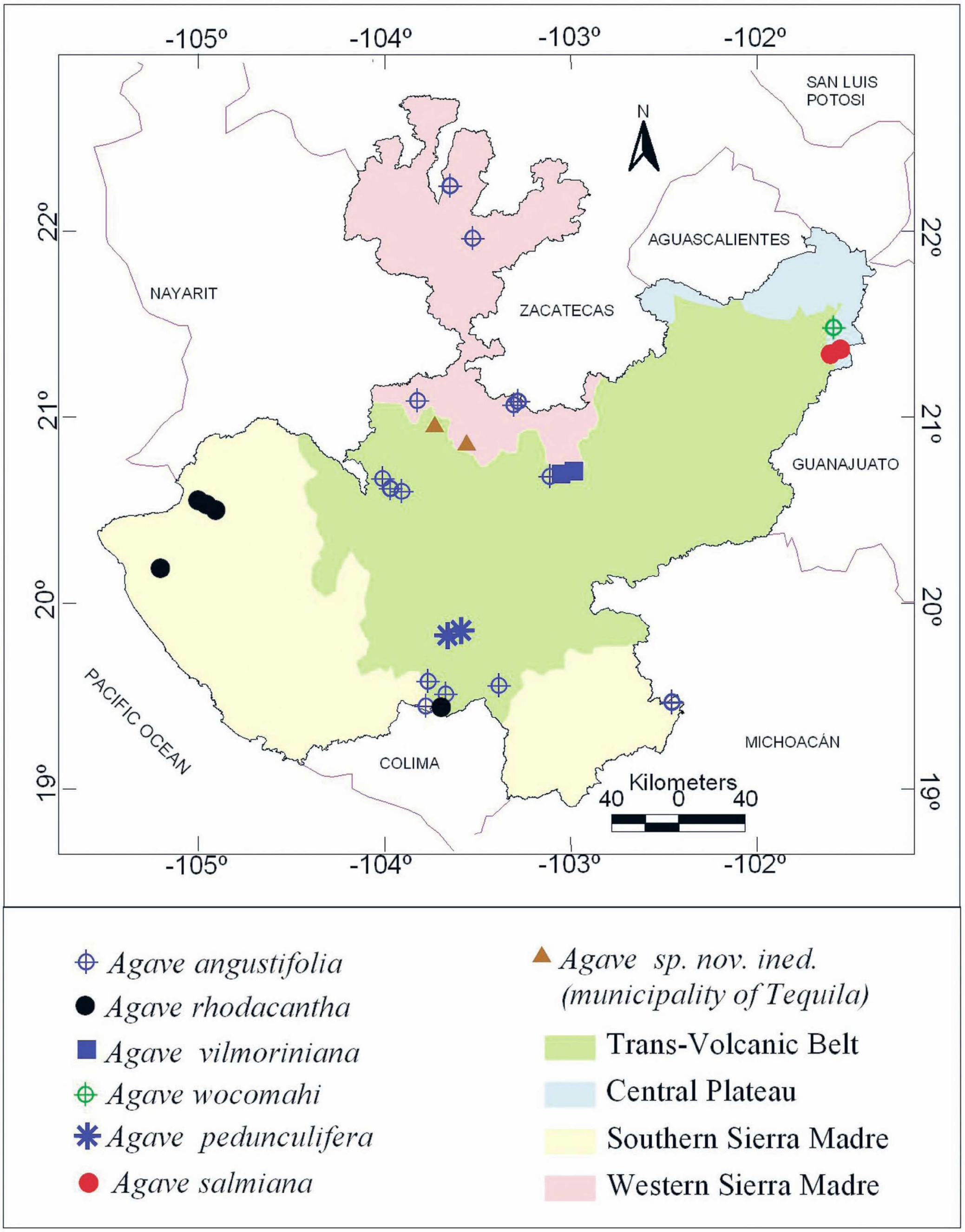


Fig. 3. Distribution of *Agave angustifolia, A. rhodacantha, A. vilmoriniana, A. wocomahi, A. pedunculifera, A. salmiana,* and *Agave* sp. nov. ined. (municipality of Tequila).

Fig. 4. ***Agave attenuata*** **thriving in rocky cliffs at 1 700 m above sea level in Sierra de Manantlán south of Jalisco. The arrows show the long stems developed by this species. Photo: Piet Van der Meer.**

based on collected specimens. As suggested by Gentry (1982), the ecological importance of these cliff-dwelling species appears to be their contribution to soil building and soil-holding capabilities on the steep rocky slopes.

Richness and Conservation Status

With 23 species of *Agave* known so far as wild plants, Jalisco state stands second place in agaves diversity in Mexico, only surpassed by Oaxaca state where García-Mendoza (2004) reported 30 species. We believe 2 more species could be present in Jalisco, namely *Agave durangensis* Gentry and *Agave striata* Zucc. The first one in Huejuquilla region, since we have collected it in the adjacent Valparaiso municipality in Zacatecas state, whereas *Agave striata* has been seen and photographed at Sierra del Laurel (Esperanza Quezada, pers. comm.), a mountainous range at Calvillo municipality in Aguascalientes state. The eastern slopes of these mountains belong to Jalisco; hence, we predict it occurs at Sierra del Laurel in the Jaliscan side, a region which has remained unexplored. On the other hand, the botanist Pablo Carrillo recently found *Agave ornithobroma* (pers. comm.) in Mezquitic municipality, into de Huichol indians region north of Jalisco. Further explorations in the zone will be necessary.

The geographic distribution of *Agave* species in Jalisco is uneven; some cover an ample range, such as the *Agave angustifolia* complex, whereas others like *A. valenciana, Agave* sp. nov. ined. (Municipality of Tequila), *A. vazquezgarciae,* and *A. geminiflora* are endemic to small areas. Among the 18 *Agave* species in Mexico that are considered within some status of protection by the Federal Government (DOF 1994), only *A. gypsophyla* and *A. ornithobroma* occur in our study area; however with the data gathered so far, we consider

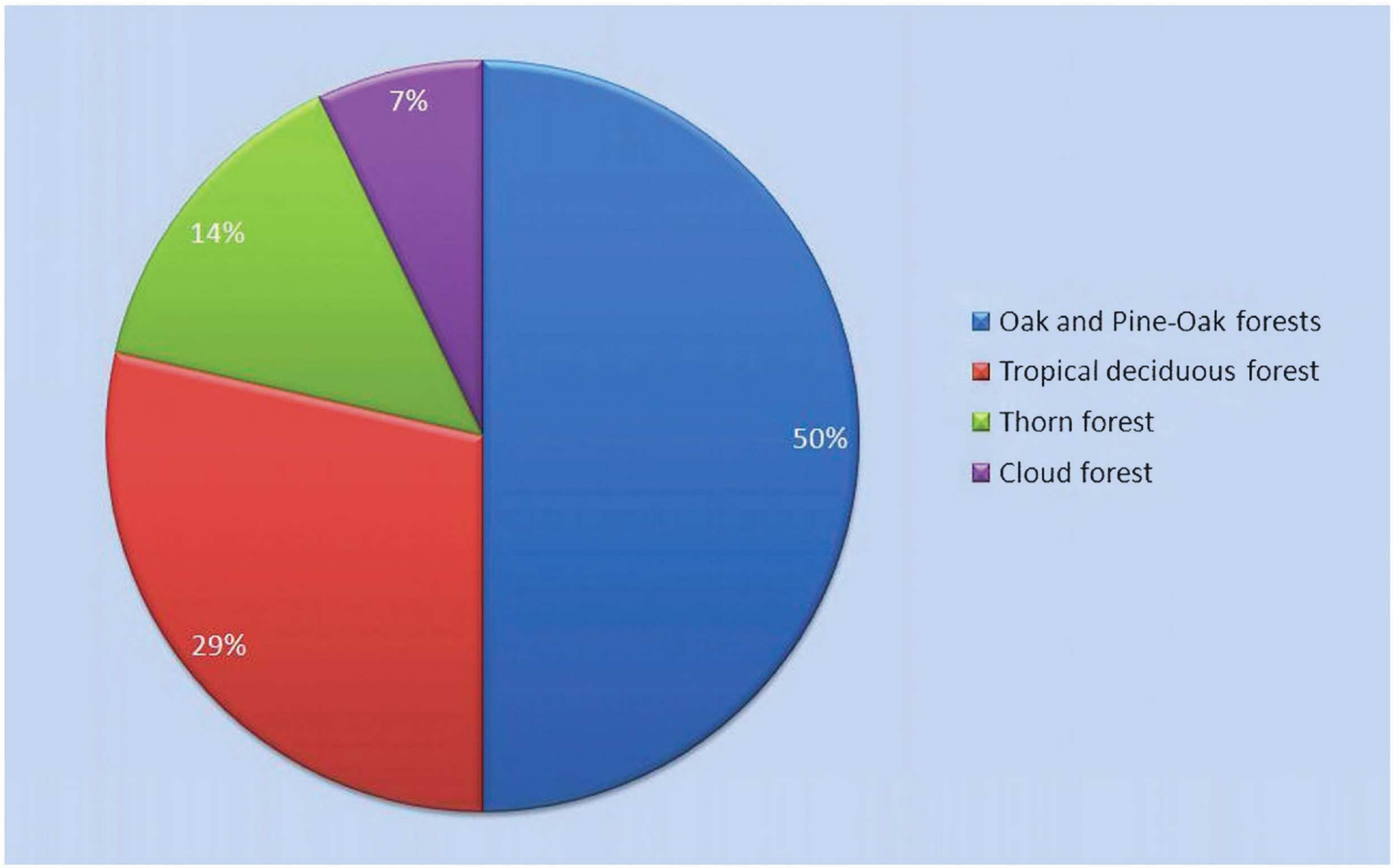


Fig. 5. Percentage of *Agave* species by vegetation type in Jalisco, Mexico.

the following taxa should be added to the list (the first three of them endemic to Jalisco): a) *Agave valenciana,* restricted to small areas of the Mascota river canyon and the Talpa river, b) *Agave* sp. nov. ined., restricted to the Santiago river basin ravines next to Tequila, c) *A. vazquezgarciae*, from Sierras Manantlán and Cacoma, and d) *A. geminiflora,* previously known only from the type locality (Ocotillo, Nayarit); we found it near "El Salvador," municipality of Tequila.

CONCLUSIONS

A thorough botanical exploration of Jalisco resulted in the corroboration and update of previous reports of *Agave* species in the state. The great diversity of *Agave* species in Jalisco is related to the geographical and geological characteristics of the state. To the authors' knowledge, this is the first extensive botanical exploration of *Agave* species in Jalisco. Documented specimens with exact geographical coordinates will provide a reliable source of information on these plants for further research. We consider that basic botanical research is essential as a preliminary step for a better understanding and rational management of plants and thus, habitat.

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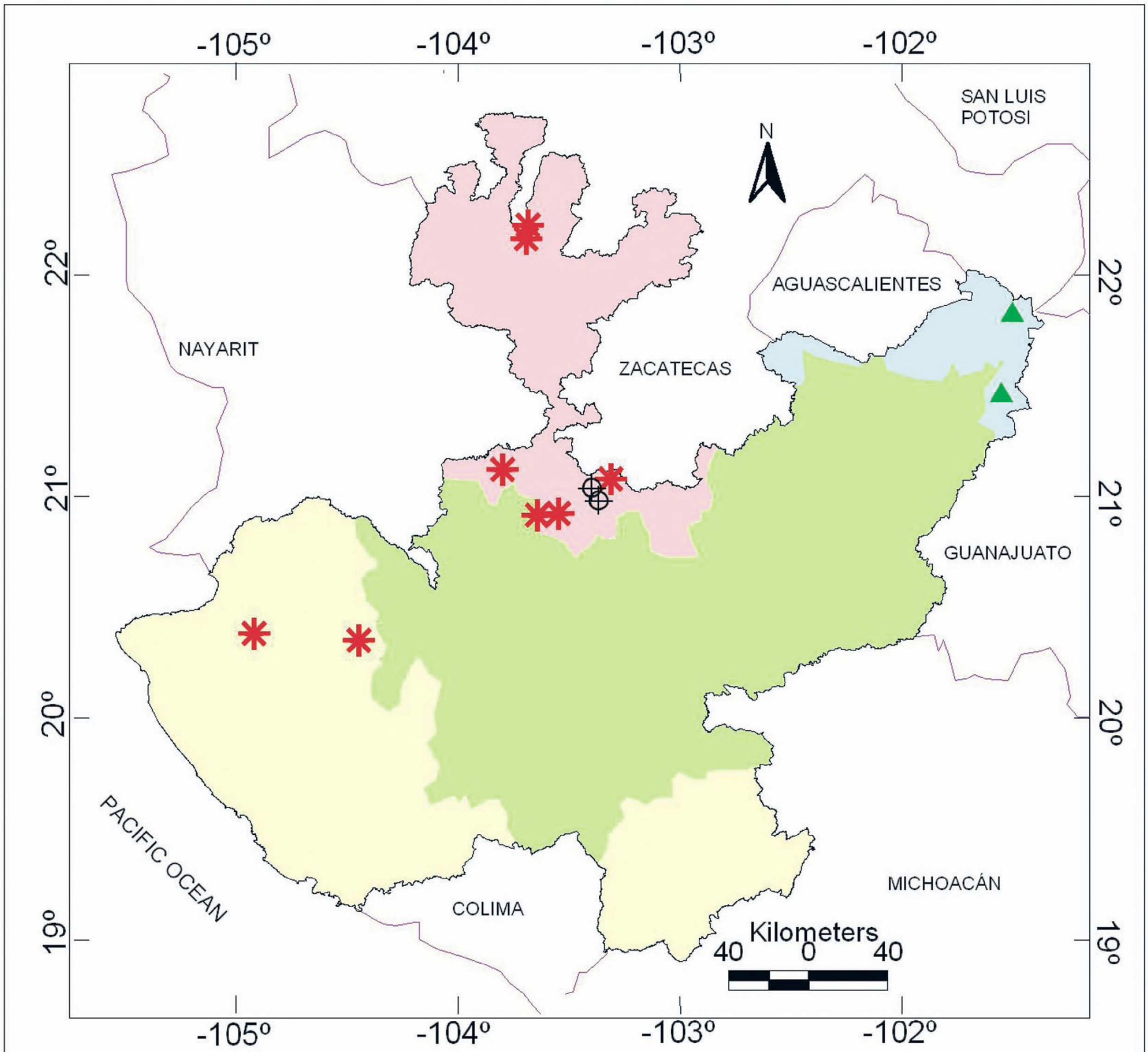

Fig. 6. Distribution of *Agave schidigera, A. filifera, and A. rzedowskiana.*

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TABLE 2. Ecological distribution of *Agave* in Jalisco, Mexico.

Species	Vegetation Type	Altitude (m above sea level)
Agave angustifolia	Tropical deciduous forest/Pine-oak forest and the ecotone from both/Thorn forest/	707–1,845
Agave rhodacantha	Oak forest/Tropical deciduous and subdeciduous forests/Ecotone oak forest–Tropical subdeciduos forest	250–1,133
Agave tequilana var. *azul*	Only cultivated	
Agave inaequidens	Oak and pine-oak forests	1,910–2,319
Agave maximiliana	Oak and pine-oak forests/Ecotone oak forest–Tropical deciduous forest	1,086–1,987
Agave gypsophila	Tropical deciduous forest	590–600
Agave valenciana	Ecotone oak forest–Tropical deciduous forest	1,182
Agave guadalajarana	Oak forest and ecotone with Tropical deciduous forest	1,689–1,850
Agave parryi	Thorn forest, *Yucca* sp. forest	2,364
Agave wocomahi	Thorn forest	1,975
Agave salmiana	Oak forest	2,532
Agave pedunculifera	Oak forest	1,910
Agave attenuata	Ecotone oak forest–Tropical deciduous forest	1,699
Agave vilmoriniana	Tropical deciduous forest	1,275
Agave vazquezgarciae, sp. nov.	Ecotone oak forest–cloud forest	1,613
Agave colimana	Tropical deciduous forest/Oak forest/ Ecotone pine-oak forest–cloud forest	801–1,167
Agave schidigera	Oak and pine-oak forests/Tropical deciduous forest/Ecotone oak forest–Tropical deciduous forest	875–2,178
Agave filifera	Thorn forest/*Yucca* forest/ Oak-Juniperus forest	2,341–2,450
Agave geminiflora	Oak forest	1,814
Agave angustiarum	Oak forest/Tropical deciduous forest	914–979
Agave sp. nov. ined. ("Colimilla" ravine, municipalities of Tonalá and Zapotlanejo)	Tropical deciduous forest	1,270-1,300
Agave sp. nov. ined. (municipality of Tequila)	Tropical deciduous forest	1,055–1,531
Agave rzedowskiana P. Carrillo, R. Vega & R. Delgad.	Oak forest	1,689

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